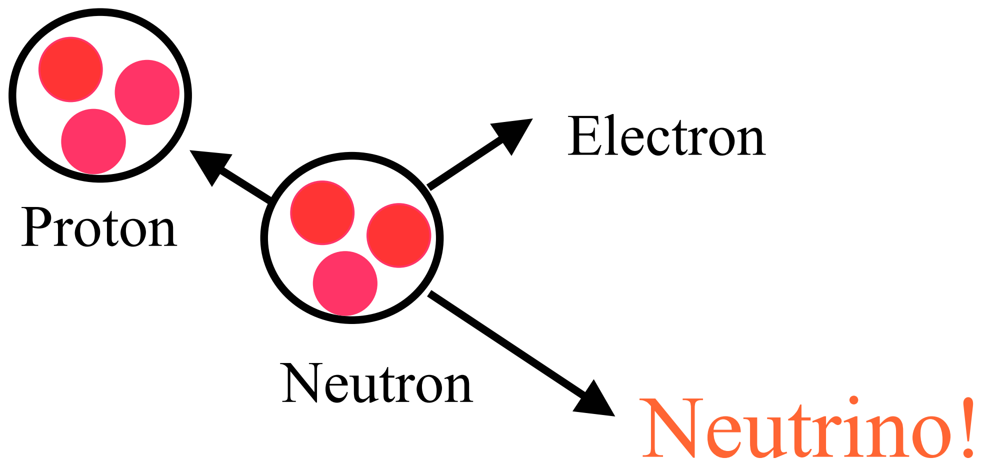
Neutrinos

or "*little neutral one*"

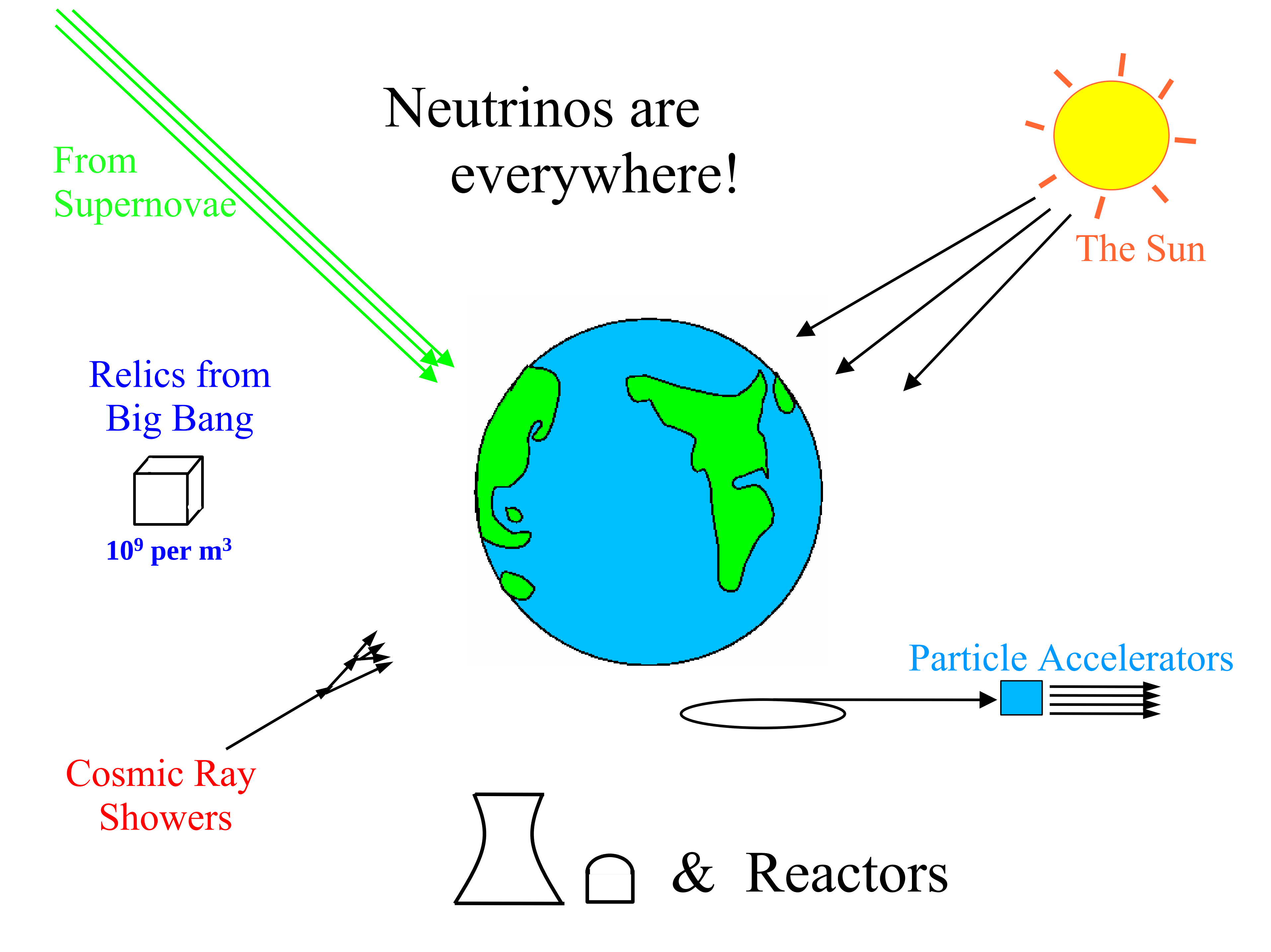
postulated by Wolfgang Pauli in 1930
to explain the missing energy in nuclear beta decay

Physicists were ready
to *abandon*
Conservation of Energy

...until Pauli
proposed this
"desperate remedy"

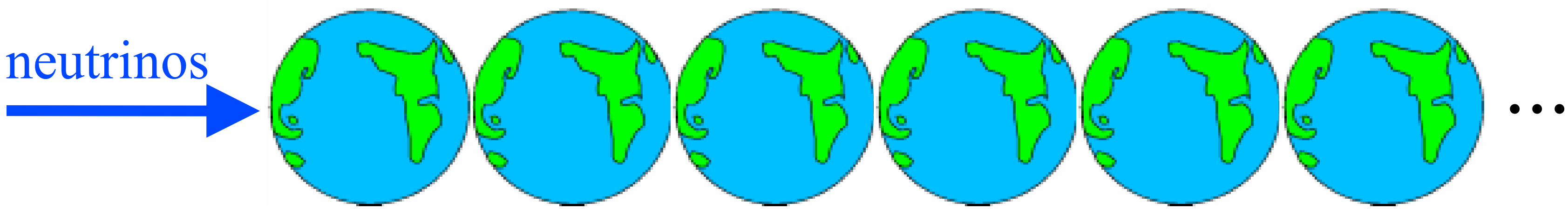


* Fundamental
* electrically neutral
* weakly interacting
* maybe massless... *maybe not!*


Neutrinos are everywhere!
From Supernovae
The Sun
Relics from Big Bang
10⁹ per m³
Cosmic Ray Showers
Particle Accelerators
& Reactors

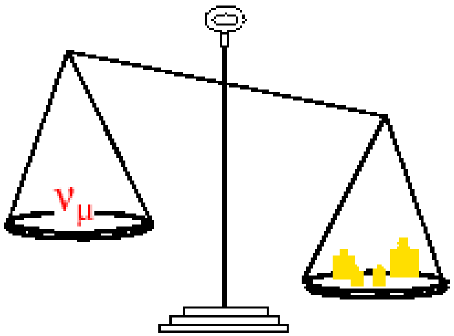
Neutrinos interact via the Weak Force
They call it weak for a reason!

Neutrinos leave a trace
100,000,000,000
times less often than protons



A neutrino has a good chance of traveling through
200 earths before interacting at all!

Fundamental questions we are trying to answer:



Why do neutrinos have tiny masses?

How does this mass affect galactic structure and "Dark Matter" in the universe?

Can they explain why there is only matter in the universe?

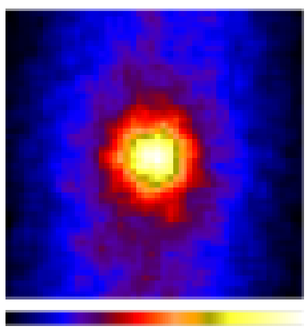
"Discoveries involving neutrinos are reshaping the foundations of our understanding of nature"

– National Research Council of the National Academy of Sciences

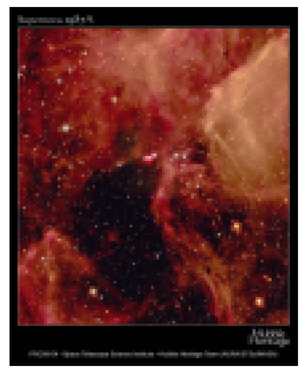
An Exciting History:

The 2002 Nobel Prize:

Raymond Davis
(solar neutrinos)



Matsatoshi Koshiba
(supernova neutrinos)



The 1995 Nobel Prize:
Fred Reines (first observation of neutrinos)

The 1988 Nobel Prize:
Leon Lederman
Melvin Schwartz
Jack Steniberger

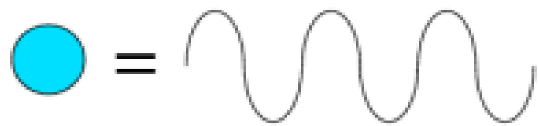
Neutrinos come in 3 types...

- electron neutrino (ν_e)
- muon neutrino (ν_μ)
- tau neutrino (ν_τ)

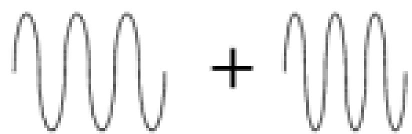
The key to understanding neutrino mass...

A quantum mechanical effect called "Neutrino Oscillations"

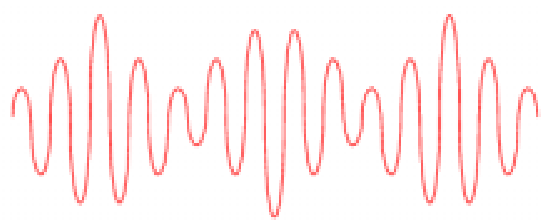
Particles can be thought of as waves...



If a wave is made up of 2 components, nearly alike



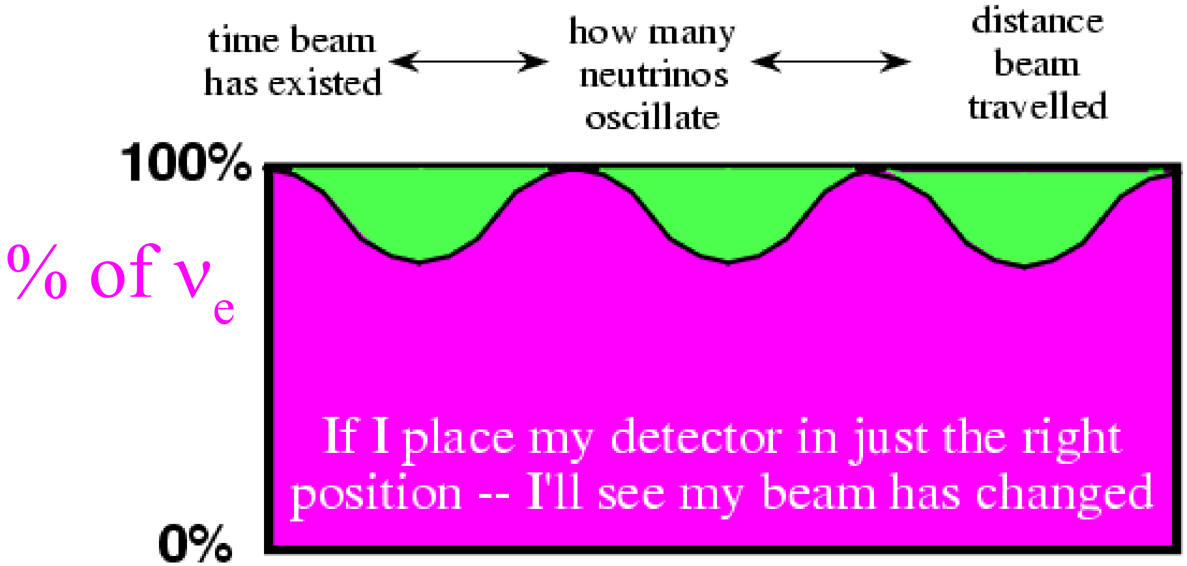
Then you get interference ... "Beats"



Like when two flutes are slightly mistuned...
The sound comes and goes

This happened because there was a *physical difference* between the flutes

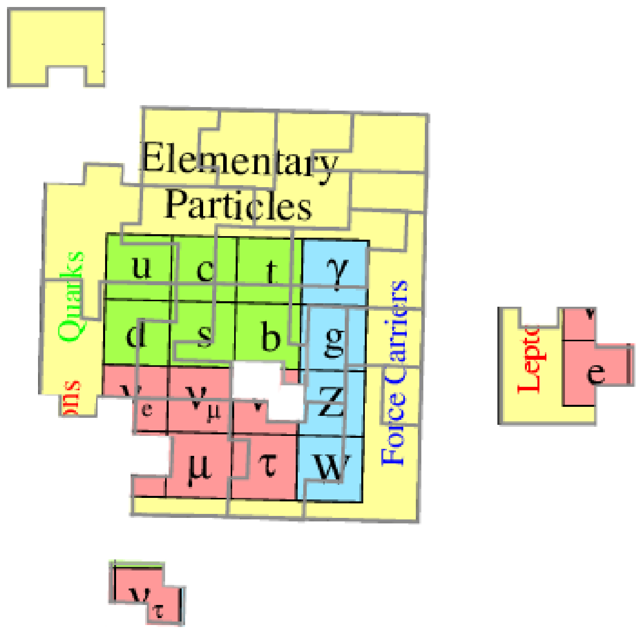
If neutrinos are made up of two waves, representing small but different masses...



- This effect is called neutrino oscillations.
- One type of neutrino is turning into another.
- This can only happen if neutrinos have mass.
- There is already good evidence for this effect.

The goals of our proposed experiment:

- Fill in missing information on how neutrinos oscillate
- Understand if antineutrinos are different from neutrinos



Finish off the
Neutrino Puzzle
in the
Standard Model
of Particle Physics

Using Reactors to Perform a Precision Measurement of Neutrino Properties

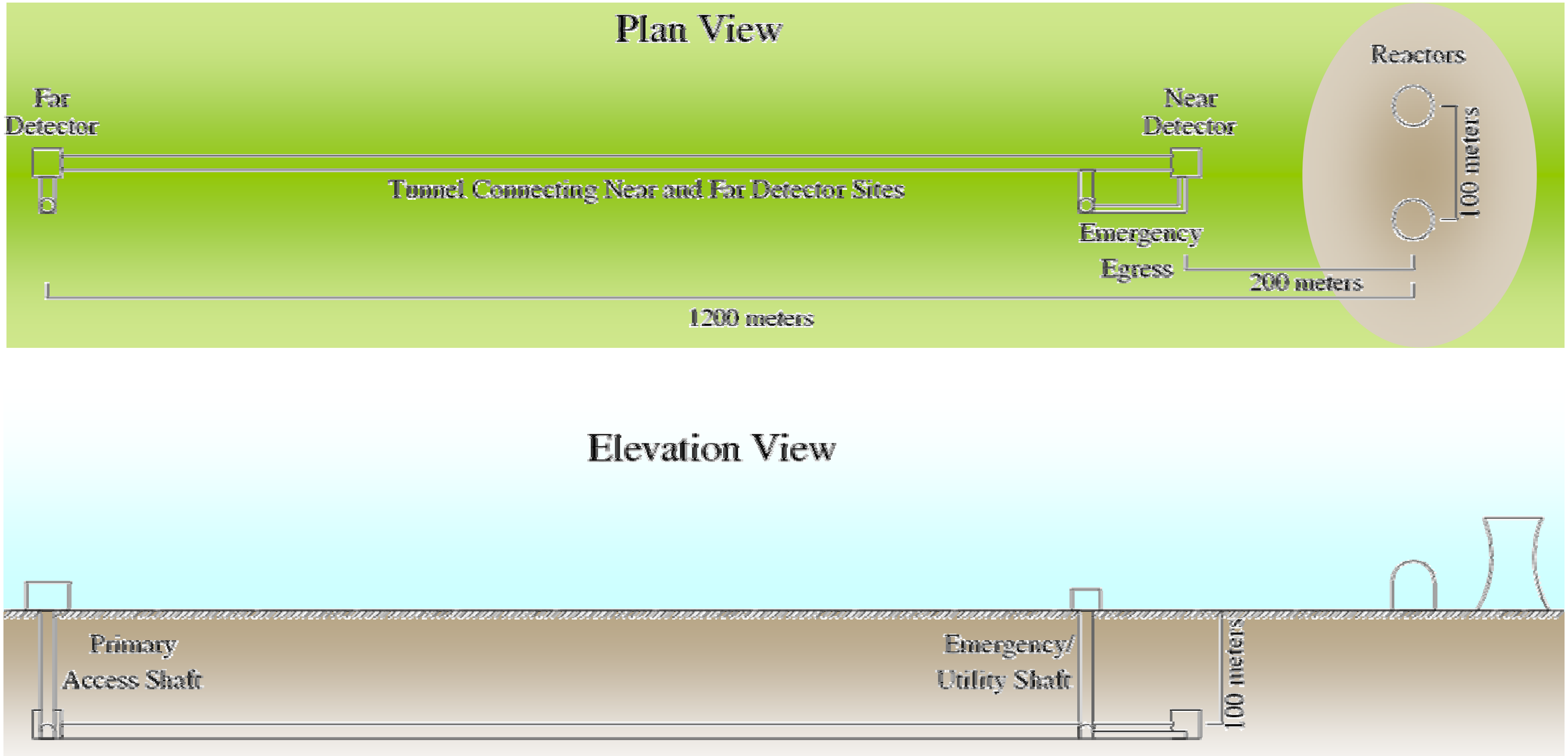
How do you design a neutrino experiment?

You need…

- An intense source of neutrinos (Reactors!)
- Of the right type and energy, ✓
- Large detectors at the optimal distances from the source,
- Protection from cosmic rays, and (Deep Underground)
- The ability to do precise calibrations. (Near and far detectors connected by a tunnel)

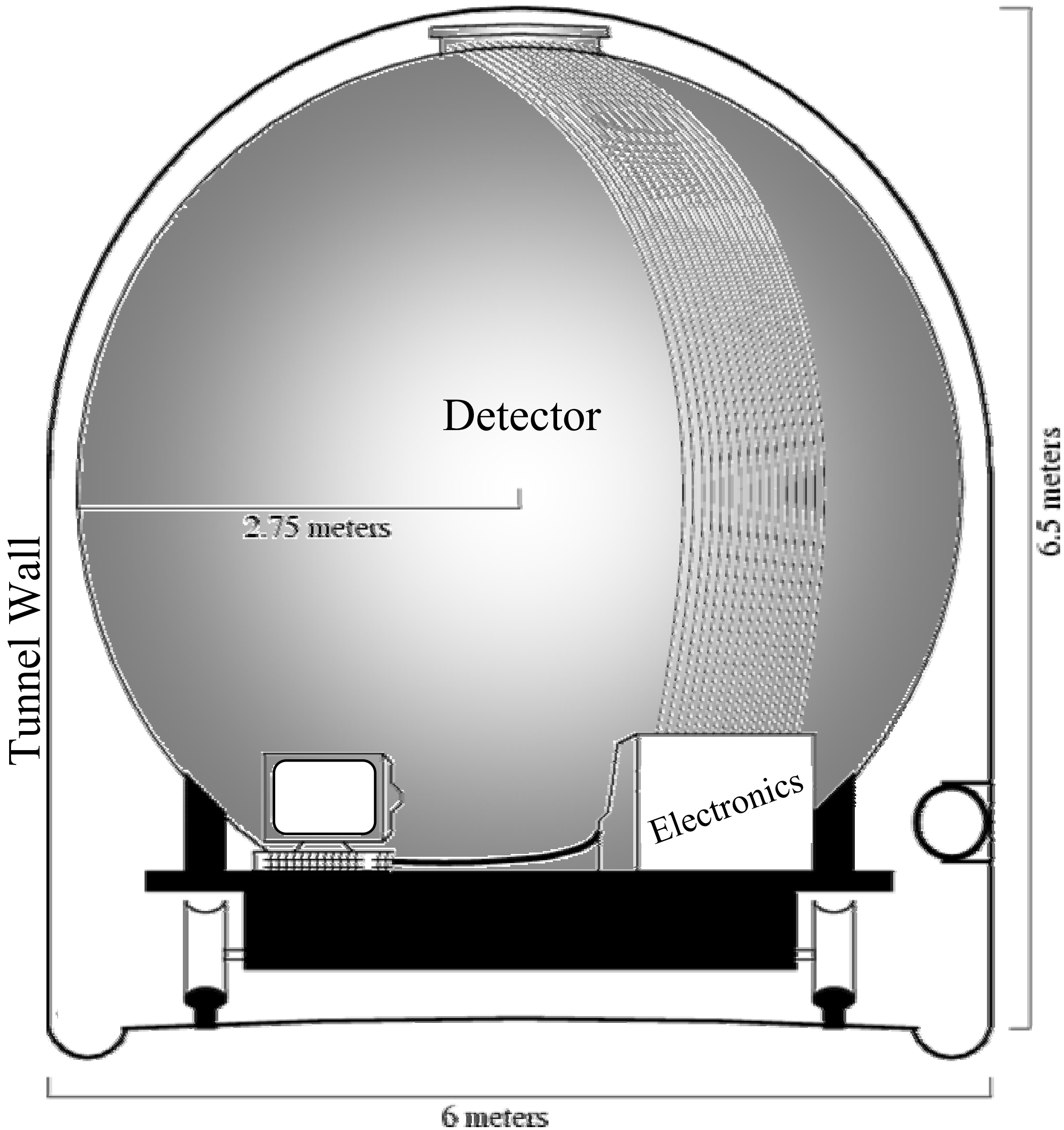
The Experiment Calls for Two Detector Sites

We are looking for neutrinos to disappear between the near and far detectors



Fermilab engineers have experience tunneling near very sensitive equipment.

Movable Detector for Precision Measurement

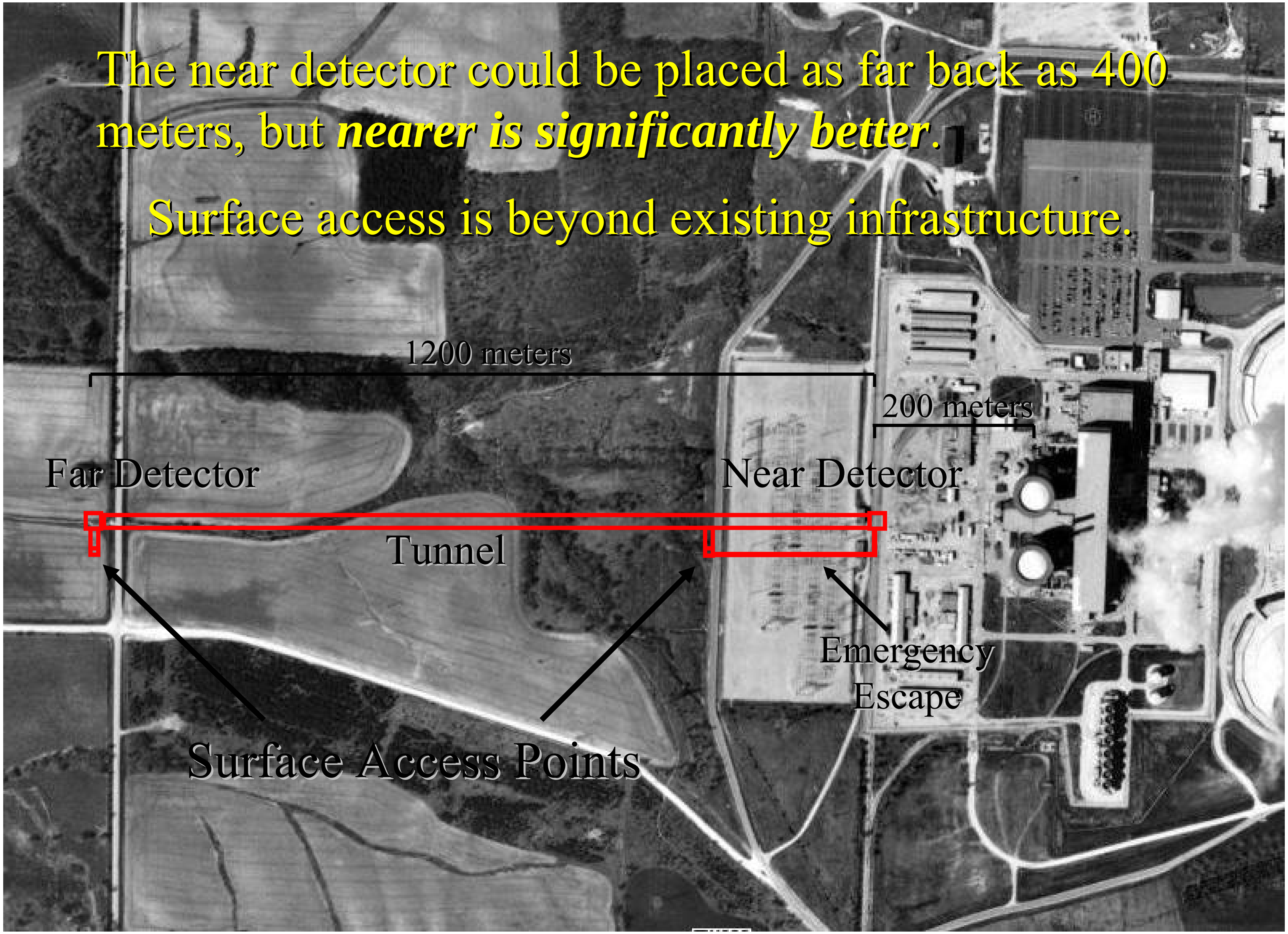


The detectors move between the far and near site for precision calibration.

Detectors are filled with 50 to 100 tons of mineral oil.

Byron, Illinois

A Possible Site Configuration



Why Use Exelon Reactors?

Nuclear Reactors are a great source of neutrinos.

Each fission generates 6 neutrinos on average.

So more power means more neutrinos.

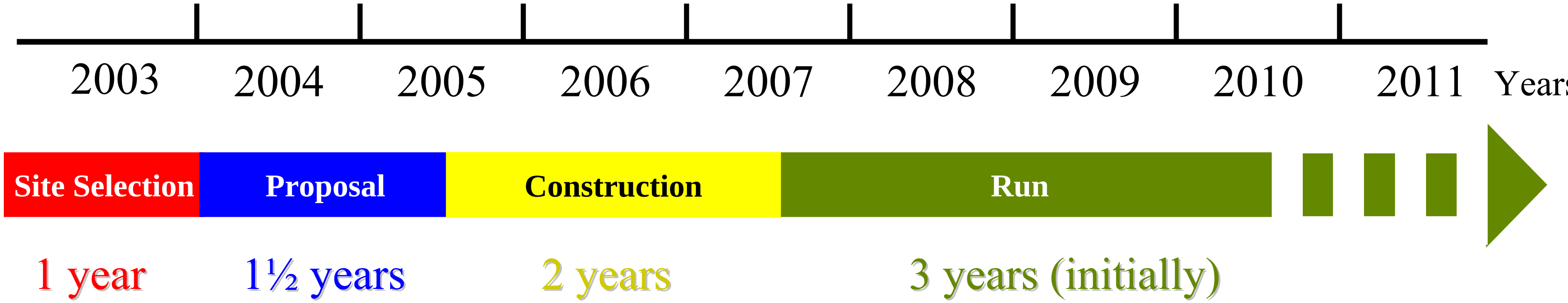
1. Exelon reactors are among the most powerful in the US.
2. Many Exelon sites are easy to access. They are close to
   - Major urban areas
   - Major airports
   - National Labs and
   - Universities

Reactor Power Performance

Rank	Reactor Sites	States	Avg MW	Max MW
1	Palo Verde	AZ	3612	3948
2	South Texas Project	TX	2346	2597
3	Braidwood	IL	2218	2451
4	Vogtle	GA	2206	2437
5	Byron	IL	2201	2451
6	Browns Ferry	AL	2179	2364
7	Limerick	PA	2175	2364
8	Peach Bottom	PA	2150	2364
9	Sequoyah	TN	2122	2331
10	Oconee	SC	2120	2633
11	Susquehanna	PA	2106	2385
12	Catawba	SC	2090	2331
13	San Onofre	CA	2071	2350
14	Diablo Canyon	CA	2065	2306
15	Comanche Peak	TX	2046	2364
16	McGuire	NC	2009	2331
17	North Anna	VA	1753	1977
18	St. Lucie	FL	1683	1845
19	Edwin Hatch	GA	1675	1889
20	Arkansas Nuclear	AR	1655	1840
21	Calvert Cliffs	MD	1645	1845
22	Joseph Farley	AL	1641	1897
23	Dresden	IL	1633	2021
24	Brunswick	NC	1606	1748
25	Surry	VA	1594	1740
26	Nine Mile Point	NY	1538	1817
27	Quad Cities	IL	1531	2021
28	Indian Point	NY	1527	2083
29	La Salle	IL	1477	2385
30	Salem	DE	1463	2364

Averages taken over the last 7 years

Experiment Timeline



Site Selection: Currently underway.

Proposal Phase: Secure funding from government agencies (NSF and DOE)

Construction Phase: Tunnel construction and detector assembly

Run Phase: Initially planned as a three year run. Results or events may motivate a longer run.

Interested Institutions in the U.S.

Fermi National Accelerator Laboratory

ARGONNE NATIONAL LABORATORY

COLUMBIA UNIVERSITY
IN THE CITY OF NEW YORK

THE UNIVERSITY OF CHICAGO

THE UNIVERSITY OF ALABAMA

Berkeley
University of California

MIT

STANFORD UNIVERSITY

CALTECH
CALIFORNIA INSTITUTE OF TECHNOLOGY 1891

UCIrvine
University of California, Irvine

UNIVERSITY OF MICHIGAN

BERKELEY LAB

THE UNIVERSITY of TENNESSEE

K-State
Kansas State University

UCLA

Louisiana State University
LSU